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SUMMARY OF THE FIRST ACTS PROPAGATION WORKSHOP

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1. BACKGROUND

The first ACTS Propagation Studies Workshop (APSW I), organized by NASA/JPL to plan propagation experiments and studies with NASA's Advanced Communications Technology Satellite (ACTS), convened in Santa Monica, California, during November 28-29, 1989. The objectives of APSW I were to identify general and ACTS-related propagation needs, and to prepare recommendations for a study plan incorporating scientific and systems requirements related to deployment of 8-10 propagation terminals in the USA in support of ACTS experimental activities.

2. WORKSHOP ACTIVITIES

Two sessions were held on the first day. R. Bauer of NASA Lewis Research Center chaired Session I, "A Review of ACTS Propagation Features," a synopsis of parameters for both the space and ground segments of the ACTS system with emphasis on elements related to propagation concerns. Topics included: an ACTS System Overview; Spacecraft Beacon Characteristics; the NASA Ground Station (NGS) Beacon Measurement Subsystem; the NGS Fade Detection Algorithm; and the Harris "Mean Squared Over Variance" fade-sensing technique proposed for NASA's Low-Burst-Rate (LBR) communication terminals. F. Davarian of JPL chaired Session II, "NASA Propagation Experiments Plan," including The View From NASA Headquarters; VPI&SU Olympus Propagation Experiments; and A Look at the ACTS Opportunity.

The second day was devoted to parallel discussions within Working Group (WG) 1 - Scientific Studies, and WG 2 - Systems Applications & Receiver Architecture. F. Davarian set the agenda with an introductory presentation. Special presentations were made by R.K. Crane (20/30 GHz Propagation Effects Study), W.J. Vogel (ACTS to Antarctica); J. Goldhirsh (ACTS - Mobile Experiment); R.M. Manning (Markov Random Process Models for Adaptive Fade Algorithms); and K.C. Allen (Pattern Recognition Techniques Applied to Adaptive Compensation). Both WGs prepared reports on their work, results of which are reproduced below.

Complete proceedings of APSW I are available in Publication JPL D-6918, edited by F. Davarian, dated December 15, 1989. The following discussion, based on elements extracted from the proceedings, emphasizes ACTS requirements and corresponding plans.

3. PLANNING GUIDELINES

Planning for ACTS propagation experiments and studies should accommodate the ACTS spacecraft specifications (e.g., beacon characteristics); goals of the ACTS program (demonstration of advanced technology such as dynamic fade compensation); trends in satellite communications (small-margin terminals, etc.), and the need to remedy deficiencies in available propagation information (such as the lack of data for some climates). Activities on the first day of APSW I were organized to provide the participants with such information.

Session I focused on ACTS spacecraft features, and Session II on propagation-related goals. General propagation needs and specific ACTS needs enumerated by F. Davarian included:

- Propagation data for VSATs with small power margins
- Propagation data on short-term fades and fade slope
- Fade countermeasures
- Nationwide joint impairment statistics
- Fade prediction and countermeasure techniques, rain attenuation models, etc.
- Unified effort to respond to ACTS propagation needs
- Provide advice and assistance to ACTS communication experimenters.

4. RESULTS OF WORKSHOP DELIBERATIONS

The two APSW I working groups deliberated on the second day, and prepared detailed reports, available in the proceedings. Those reports are summarized below.

4.1 WG 1 - Scientific Studies

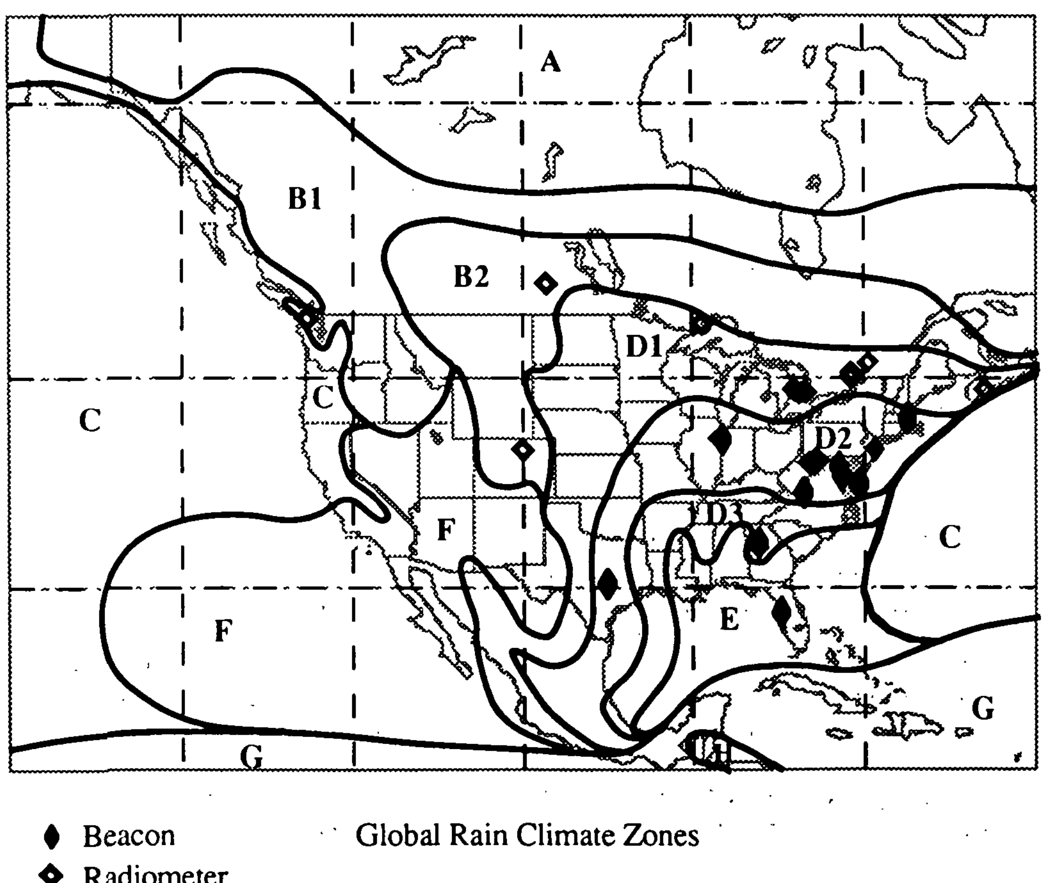
WG 1, Chaired by Robert K. Crane, Dartmouth College, considered propagation experiments that could be conducted with ACTS, and recommended experiments to:

- complete models for the prediction of attenuation statistics in climate regions of the USA that have not been studied
- obtain a statistical description of attenuation for annual time percentages of 1% to 10% needed for the design of low-margin communication systems
- provide a statistical description of the physical processes that give rise to attenuation in the next higher frequency window (~ 90 GHz) needed for the design of higher frequency communication systems
- obtain information needed for the evaluation of the schemes for attenuation compensation employed in the ACTS program and to provide additional data for the design of new mitigation techniques
- explore the use of the 20/30 GHz band for the development of new services, and
- obtain information on the vertical structure of the atmosphere for use in refining attenuation prediction models and in developing inversion algorithms for remote sensing systems.

WG 1 gave consideration to available propagation data for North America, summarized in Fig. 1, noting that most of the rain climate zones have not been well sampled. At least three years of observations were recommended for five of the seven climate regions within the USA for at least 7 new locations, as follows:

Climate Zone	Institution	Location
B2	NOAA/WPL	Colorado
C	?	W. Washington
D1	Michigan Tech	Michigan
D1	Dartmouth College	New Hampshire
D3	?	Tenn., N. Carolina
E	?	Florida
F	Jet Propulsion Lab	California

Three additional climate regions were identified as critical for construction of valid rain attenuation models on a global basis: the Arctic (zone A) and the tropics (zones G and H). The steerable ACTS antenna could be used in conjunction with radiometer measurements for observations in these regions. To extend existing data to time percentages above 1%, measurements were also recommended for zones B1 and D2, in the latter at locations already represented in the data base (Austin, TX; Blacksburg, VA; and Washington, D.C. area).



Global Rain Climate Zones

Figure 1. North American Slant Path Observations

For several applications, the complementary capabilities of beacon and radiometer measurements were noted. WG 1 recommended radiometer measurements in support of beacon measurements to obtain data for annual time percentages of 1% to 10%; for identification of the physical processes that cause propagation impairments; and to investigate the vertical structure of the atmosphere. For the compilation of attenuation data for time percentages of 1% to 10%, WG 1 recommended the use of radiometers to establish accurate clear-sky baseline levels and extend the dynamic range of the beacon measurements down to 0.2 dB, while complementary beacon measurements are required to extend the dynamic range of the radiometer terminals. This combination is necessary to provide the required dynamic range of 0.2 dB to 15 dB with an accuracy of better than 15% for the attenuation measurements. WG 1 identified the requirement for a beacon dynamic range of 26 dB (6 dB above the nominal received level to 20 dB below) for this application.

For development of impairment mitigation techniques, WG 1 recommended recording fading signals at a sampling rate of 1 Hz for the compilation of statistics of fade duration, interfade intervals, and fading rates, and to provide time series data needed to test the behavior of fade detection and forecast schemes. Measurements of signal level statistics for propagation through trees and roadside obstructions were recommended to support a move to higher frequencies by the land mobile-satellite services. In particular, measurements in Maryland were recommended to augment the existing UHF and L-band data base.

WG 1 made several general recommendations to ensure data quality and uniformity of data processing. These included: deployment of an optical rain gauge at each site, and use of a Wang device that can identify the precipitation phase (rain, snow, ice) at locations that experience significant occurrences of mixed precipitation; measurement of surface weather conditions at each site; use of a single data format and set of data processing algorithms by all experimenters; establishment of uniform instrument-calibration procedures before the experiment begins; uniform documentation and data preparation/reporting procedures should be used; and a uniform procedure for handling equipment downtime should be established prior to the measurements.

4.2 WG 2 - Systems Applications & Receiver Architecture

Working Group 2, Chaired by David V. Rogers, COMSAT Labs, considered a variety of communication system needs (not necessarily completely consistent with scientific requirements identified by Working Group 1). A variety of propagation requirements for future systems, with particular emphasis on ACTS needs and applications, were identified:

- dynamic allocation of communication resources, with related need for details of individual propagation events (fading rates, fade durations and interfade intervals at specified thresholds, etc.), and associated control algorithms;

- small-margin systems (VSATs) and similar requirements for adaptive decision-making at low fade levels where gaseous absorption, cloud losses, and tropospheric scintillation components should be separately identified;

- mobile systems, which have a secondary frequency allocation in the Ka-bands, and the related problems of multipath and shadowing/blockage;

- dual-polarization system studies (e.g., effects of power control on crosspolar interference, joint coding for fading and depolarization), possibly requiring propagation study;

- the JPL Personal Access Satellite Service (PASS) terminals, which will be small and transportable; and

- site diversity with small terminals at small separations.

Most of the aforementioned needs can be adequately addressed by monitoring the ACTS beacons, although supplementary radiometric (skynoise) data were also recommended.

WG 2 considered the desirability of recording various propagation parameters and the associated sampling bandwidth, dynamic range, and resolution for measurements conducted with the ACTS beacons, and recommended that the terminal be configured to record the following propagation and meteorological parameters:

- 20- and 30-GHz GHz beacon receive signal levels;

- 20- and 30-GHz GHz radiometric skynoise (brightness) temperatures;

- point rain rate near the terminal;

- atmospheric temperature and humidity at the earth's surface; and

- ambient temperature of sensitive components affecting the measurement of beacon receive signal level and radiometric skynoise temperature.

WG 2 recommended that: the terminal be designed to sample the beacon receive signal level at rates up to 100 Hz (though data may be recorded at lower rates during normal operation); that detection bandwidth of the beacon receivers vary with sampling rate in accordance with the Nyquist criterion; that radiometer data be sampled at the same rate as the beacon data for ease of handling; and that the recorded data include the periodic calibration levels. Humidity and temperature can be sampled as slowly as once every 10 minutes to conserve data storage space. Time stamps stored with the data should be in terms of universal time, and accurate within ± 2 seconds.

Effective mitigation of Ka-band path attenuation requires properly-designed algorithms to identify and respond to fading in real time. Five major areas were identified and recommended for investigation and development: fade detection; propagation effect identification; baseline determination and extraction; adaptive fade response and compensation; and frequency scaling. Appropriate propagation parameters should be measured and recorded with regard to the requirements of these five areas.

WG 2 considered a variety of questions regarding the terminals required for the JPL ACTS propagation measurements, noting that substantial development in these areas is ongoing under the NASA Propagation Program, and that the results will strongly affect any final design. The main recommendations included:

- for the beacon measurements: 0.1 dB resolution; accuracy of 0.5 dB rms believed achievable; 10-15 dB dynamic range needed to give reliable data in the 0-5 dB range (of particular interest for VSATs and adaptive algorithms);

- it is preferable to continuously monitor an injected signal from a stable source for calibration but this approach is expensive (easier to implement with digital receiver);

- a rain gauge is essential, and temperature and humidity data are desirable;

- a reliable Uninterruptible Power Supply (UPS) is essential;

- a self-test feature is highly desirable (could be remote);
- data collection with a 12-bit A/D was a popular choice; storage should be binary with a time stamp; real time displays with variable time histories (e.g., 8 min, 2 hr, 1 day, 2 days);
- a modem interface to a phone line is necessary for remote monitoring and checking;
- all terminals should be of standard design and produce standardized data.

Propagation experiments that make use of the communications channel capabilities of the ACTS (both Low Burst Rate and High Burst Rate modes) were considered, although beyond the capabilities of envisaged ACTS beacon-monitoring terminals. The HBR mode provides over 800 MHz of bandwidth, with an EIRP of nearly 60 dBW, in a nonregenerative hard-limited "bent-pipe" mode. Experiments were considered that would make use of a channel-characterization signal transmitted on the uplink from a single reference station in a broadcast mode to any of 3 selected antenna systems on the downlink. These experiments provide unique and novel capabilities that cannot be obtained with the ACTS beacons, and could increase the scope and value of ACTS in providing Ka-band propagation results for system applications. These experiments may be classed into the following categories:

- channel probe experiments to measure the impulse-response function of the radio transmission channel in conjunction with performance assessment (e.g., BER);
- Ka-band aeronautical mobile experiments in the HBR mode to measure and evaluate transmission characteristics of Ka-band aeronautical mobile links, including signal fading, elevation-angle dependence, E_b/N_0 as a function of aircraft antenna gain, and effects of aircraft surface multipath on system performance;
- Land mobile-satellite experiments to establish the feasibility of and requirements for mobile satellite systems at 20 and 30 GHz; acquire a data base of fading caused by trees and terrain at these frequencies; and evaluate the advantage of spread spectrum techniques to overcome terrain multipath.
- Outer/inner coding techniques based on concatenated coding with combined (e.g., Reed-Solomon and convolutional) codes for adaptive power control, where the two coding schemes are invoked separately to provide graduated levels of coding gain.